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PULSE CROP GERMPLASM DEVELOPMENT
INITIATIVE FOR SASKATCHEWAN

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Pulse Crop Germplasm Development Initiative For Saskatchewan

Final Report
December 31, 2002

Project No. 970000162

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Abstract

The project involved genetic improvement of quality and disease resistance for Saskatchewan pulse crops. We developed dry beans with improved resistance to common bacterial blight and bean common mosaic virus, and extra early maturity. For chickpea, we developed kabuli and desi breeding lines with better ascochyta resistance , earlier maturity and better seed type. For pea, we converted the breeding program to powdery mildew resistance, improved bleaching tolerance in green pea, and made improvements in resistance to Mycosphaerella blight. For lentil, we improved the quality and yield of red lentis for international markets, and developed large green lentils with earlier maturity and large seed size. The results will lead to new varieties that improve the value and productivity of pulse crops in Saskatchewan.

Executive Summary

The project involved research and development focused on specific germplasm development issues of importance to four of Saskatchewan's pulse crops. We developed adapted breeding lines with specific improvements for each crop as a way to improve the genetic base available to pulse crop breeding programs. Much of this work was accomplished with assistance and free exchange of germplasm from pulse breeding programs in the USA, Australia and international centers like ICARDA and ICRISAT.

Dry Bean. We developed a system for screening and introduction of common bacterial blight resistance genes into locally adapted germplasm. Resistance to seed-borne blights will be a key feature of future seed production systems for this crop in Saskatchewan. We were also able to implement molecular marker assisted breeding for increasing the level of bean common mosaic virus, a disease of great concern in seed multiplication. By combining genes for early maturity from many different sources, we were able to develop lines with earlier flowering and maturity compared to the earliest available parental lines, setting the stage for development of extra early bean varieties in future. We were also able to start developing breeding lines with better adaptation in many bean market classes that will be increasingly important to our trading relationships over the next 5-10 years. All these characteristics will be important components in the development of an expanded and stable dry bean industry in the province of Saskatchewan.

Chickpea. Through collaborations with other institutions, we were able to greatly improve the base level for ascochyta resistance in both desi and kabuli chickpea in comparison to Sanford and Dwelley. We were also able to reduce the maturity for chickpea breeding lines through introduction of extra early maturity genes from international germplasm sources. Through this project, we were able to also form strategic collaborations with chickpea ascochyta research groups in Syria, USA and Australia. In the next few years, we will see a marked improvement in the ascochyta resistance of new varieties. In combination with new fungicide technology, the chickpea crop production scenario in Saskatchewan will become much more stable.

Pea. We successfully and rapidly converted the pea breeding program to powdery mildew resistance. This trait is now an important consideration for pea producers across the province, particularly during the drier segments of the climatic cycles. In the specific case of green pea quality, we were able to effectively and rapidly implement genetic improvements in resistance to bleaching. We should see short to medium term real economic impacts of these two traits. In addition, we were able to make steady progress toward improvement of Mycosphaerella blight, a difficult breeding objective in pea.

Lentil. By focusing specifically on improvement of quality, we have greatly improved our chances of becoming the world's preferred supplier of red lentil. New breeding lines selected for plumpness and productivity were highly acceptable to international buyers. We will be able to compete across the full spectrum of size classes. In the case of large green lentil, we improved the genetic basis for the combination of earlier maturity with large seed size. Increased average value per acre should result form the stabilizing effects on yield and quality.

This project is already having impact commercially. Commercialization opportunities for new varieties were made available to Select growers through the Variety Release Program of Saskatchewan Pulse Growers, particularly in the case of chickpea, lentil and pea varieties that show significant improvements in yield, quality and disease resistance. The improved genetic improvement capability for dry bean breeders will have commercial impact in the next few years as earlier maturing, disease resistant varieties of new market classes become available.

1 Background

The objective of the project was to accelerate development of pulse crop germplasm Saskatchewan (dry bean, chickpea, field pea and lentil) for selected traits involving disease and quality combined with better adaptation to Saskatchewan. Progress through conventional breeding for these traits is difficult and each requires special emphasis through specific long-term germplasm improvement. This project was designed to ensure that the downstream pulse breeding programs remain competitive on a global scale. This will assist the Saskatchewan pulse industry reach and maintain a competitive position in the production, processing and export of the four major pulse crops. The major areas of germplasm development were improved disease resistance, improved adaptation and improved marketing characteristics.

2 Technical Report

The project was developed as a series of crop specific sub-projects, each with specific goals. Progress for the reporting period is summarized below for each crop and sub-project.

2.1 Dry Bean

2.1.1 Development of germplasm with improved resistance to major seed-borne bacterial diseases - common blight, halo blight and bacterial brown spot.

Development of dry bean germplasm with common blight (*Xanthomonas campestris)* resistance continued throughout the project. Numerous multi-parent crosses were made with most of the known sources of blight resistance available in the USA and from CIAT. Reliable field screening techniques in an isolated nursery were developed in collaboration with Dr. S. Banniza in 2001. We were able to injure and inoculate to reliably develop leaf infections in the field (Figure 1).

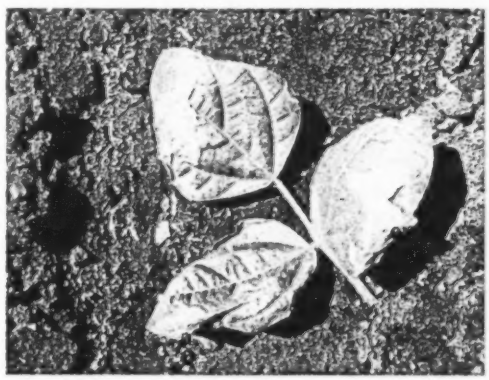

Figure 1. Classic symptoms of common blight on dry bean leaf.

We were able to successfully implement reliable marker-assisted selection methods for most of the well-characterized sources of common blight resistance developed in North America. Through collaborations with researchers in the US and Ontario, we have been able to reliably introduce at least 3 unique sources of CBB resistance into the breeding program. Based on these results we have developed a molecular-marker assisted applied research strategy in conjunction with Dr. Kirstin Bett of the Department of Plant Sciences. Many of the sources of blight resistance are poorly adapted to Saskatchewan so we have opted for a strategy of marker-assisted selection combined with recurrent selection. A system of direct back-crossing will be implemented when additional pathological information for Saskatchewan isolates of common blight becomes available.

Until now, we have not experienced severe outbreaks in the main bean breeding nurseries because the crop was protected by copper sulphate sprays at critical growth stages. In 2002, however, a severe outbreak occurred as a result of extremely favourable environmental conditions for the disease. We suspect that the high humidity in the second half of the season combined with an extremely severe grasshopper infestation created an epidemic in most nurseries in 2002. As a result we were able to confirm that many advanced breeding lines now show improved levels of tolerance to common blight. A total of 17 advanced yield nurseries were evaluated for common blight reaction in 2002 at Outlook, and final selection decisions were based on both yield and blight reaction. Table 1 shows partial results from Bean Advanced Yield Test 8 as an example.

Table 1. Performance of pinto bean breeding lines in Bean Advanced Yield Test 8 in 2002

Line	Yield			%	Common	Pod	Days to	Maturity
	Oxbow	Outlook	mean	Pintium	blight	clearance	flower	rating
	kg/ha				1-5	1-9		1-5
CDC Pintium	1581	2267	1924	100	2.9	9	46	2
CDC Pinnacle	1744	1979	1862	97	2.1	7	51	5
CDC Minto	2053	2513	2283	119	3.1	6	50	5
1091M-2	2110	2055	2082	108	1.9	6	49	4
1091M-28	2178	1813	1995	104	1.8	7	50	5
1091M-31	1934	1798	1866	97	1.2	8	50	5
1091M-40	1905	1368	1636	85	1.5	6	51	5
1091M-43	2007	1747	1877	98	1.7	7	50	5
1091M-46	2021	1764	1892	98	1.9	7	49	4
1091M-63	1695	1487	1591	83	1.8	6	48	4
1091M-64	1868	1274	1571	82	1.4	7	51	5
1091M-76	2173	1451	1812	94	1.6	6	51	5
1091M-113	2237	1714	1976	103	1.9	7	48	5
1070M-1	1599	2543	2071	108	2.0	9	48	3
CV	10.3	18.2	14.3	1.3	17.3			
LSD	360	96			0.7			

Common blight scores at Outlook only: 2 reps of leaf ratings in August; 1-no symptoms, 5 heavy damage
Pod clearance scores: 1 - 10% above cutterbar, 9 - 90% above cutterbar
Maturity rating: 1 - very early; 5 - late

Significant improvements in blight scores were obvious for various pinto breeding lines, without sacrificing yield or maturity. We have also confirmed that direct introduction of germplasm that lacks resistance to local isolates of common blight can result in severe crop damage. Future efforts to develop adapted varieties of exportable market classes, for example mayacoba, flor de junio and flor de mayo types for Mexico, must include an intensive blight resistance breeding component (see Figure 2).

Figure 2. Photograph of bean observation nursery in September 2002. New export market classes exhibit late maturity (green plots) and severe common blight infection (brown leaves) compared to adapted lines (front center plot).

The emerging bean seed industry in Saskatchewan is well aware of the potential problems caused by common blight through seed transmission. (Figure 3). We were able to assist growers and agronomists in detection and protection methods during the project.

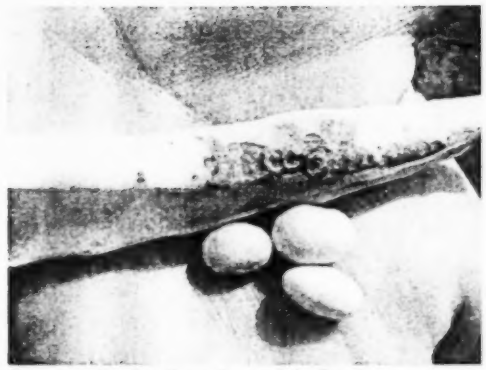

Figure 3. Pod and seed infection - common bacterial blight.

Up to now, the bean seed industry has relied on a combination of isolation, seed treatment and foliar copper sprays to reduce the incidence of blight. Agricultural streptomycin will be phased out of Canadian agriculture in the next few years. As part of the Pulse Canada Research Strategy, we intend to develop a national plan for introgression and backcrossing of blight resistance into superior genotypes over the next few years. This effort will be a collaboration with all bean breeding programs in Canada. Some additional research will be required to determine the effects of combining more than one source of resistance in the same variety.

Progress on germplasm development for resistance to halo blight and brown spot was less consistent. Differential strains for halo blight race differentiation were obtained but have not yet been used to develop molecular markers or reliable field screening methods because of potential confounding with common blight. However, we do now have access to the diagnostic isolates for halo blight and have confirmed that our laboratory methods are reliable. In future, as costs for marker development are reduced, it may be feasible to quickly develop reliable molecular markers for the various races of halo blight.

Bacterial brown spot is not well-characterized in the North American bean research community at this stage and we and information on sources of resistance and on pathogen race structure is not readily available. However, at an international conference in South Africa in 2002, several research groups initiated collaborations on development of resistance and molecular markers for both halo blight and bacterial brown spot. The project is lead by scientists from the USA (genetics and molecular biology) and South Africa (plant pathology). We will attempt to link up with these collaborative efforts in the next two years.

2.1.2 Development of germplasm with resistance to bean common mosaic virus, the major seed-borne viral disease threat.

Our laboratory is now fully capable of reliably screening for the marker closely linked to the I gene that confers resistance to bean common mosaic virus (BCMV). Much of the black and navy germplasm carries I-gene resistance, but most of the coloured bean germplasm sources are deficient. Over the past 5 years we have been able to develop

adapted breeding lines in most market classes of interest to Saskatchewan over the next 10 years, including pinto, great northern, small red, and various pink types like flor de mayo. The breeding line SC11745-3, developed in collaboration with CIAT, carries the I-gene marker. It will be considered as candidate for release as a variety in Februry 2003 at the PRRCG meeting in Edmonton.

Viral infection continues to be problematic for bean breeders in Canada. Many current varieties are resistant. In the 2000-2001 cropping cycle, at least two bean breeding programs were faced with seed multiplication difficulties attributable to bean common mosaic virus (BCMV) infection of seed grown in the USA. Breeder seed multiplication fields grown in the Pacific North West are at risk from aphid transmission of this virus.

The use of the I-gene molecular marker, allowing us to screen 3-way F_1 plants for presence or absence of the dominant *I* gene, is now routine in the pulse molecular biology lab. In the summer of 2001, pre-breeder lines of new CDC and AAFC bean varieties were sown for DNA extraction to test for presence of the I-gene molecular marker. In the fall crossing cycle, tri-parental F_1 plants were once again screened for the presence of I-gene using the markers system and we have continued this system for identifying F_1 plants that carry the marker. In some cases, the I gene marker can be used to help identify hybrid plants in situations where parents have similar morphology.

In the fall 2002 crossing block for the CDC breeding program, 46% of the parents scored positive for the I-gene markers. In the pinto group, the I-gene marker was present in most of the advanced pinto breeding lines in use as parents for the first time.

2.1.3 Development of germplasm with extra early maturity through wide crossing between Andean and Mesoamerican gene pools

The ability to withstand cold spring soil temperatures would reduce time to emergence and flowering delay in dry bean production. It may also be possible to introduce some degree of frost tolerance into dry bean.

At least two species in the tertiary gene pool, *Phaseolus aborigineus* and *P. angustissimus* have been shown to have improved ability to recover from frost in comparison to common bean, both in the field (1999) and in controlled environments. We have modified protocols for wide hybridisation with common bean with the ultimate objective of transferring useful frost tolerance traits to common bean germplasm. F_1 hybrids can made in both directions with *P. angustissimus* this species. Hybrids are sterile, so the next step underway is development of reliable embryo rescue techniques so that a congruity backcrossing scheme can be developed. Dr. Faiz Ahmad of Brandon University collaborated with us to develop protocols to eventually produce fertile interspecific hybrids. Additional funding for this aspect of the project was obtained from Saskatchewan Pulse Growers.

A series of populations combining all of the known earliest sources of germplasm was developed in collaboration with CIAT bean research scientists in 1996-98. Three

populations combining early maturity sources were selected as candidates for developing extra early maturity. The pedigrees are as follows.

DC11800 = Othello x ((Rabia de Gato x G2883)F1 x (Othello x Canario 107)F1)F1/-
DC11801 = Earliray x ((Rabia de Gato x G2883)F1 x (Othello x Canario 107)F1)F1/-
SC11801 = Expresso x ((Rabia de Gato x G2883)F1 x (Bola 60 Dias x Viva)F1)F1/-

F_5 and F_6 microplots derived from single plants selected from 1998 microplots were grown again in 1999 under extreme conditions. Single plant selections were made again. About 500 progeny rows were established in 2000 for characterization and selection of the earliest possible germplasm for use as parents in the breeding program over the next two years. In the summer of 2001 all selected lines (more than 300) were grown in plots at two locations to determine the variability in phenology. Due to severe drought conditions, reliable data were obtained only for days to flowering. Yield and maturity were affected by drought, especially at Rosthern. Based on preliminary analysis of flowering data and plant canopy analysis in relation to check varieties like CDC Pintium, we are confident that additional gains can be made in selection for early maturity in short season areas. These experiments were repeated in 2002 at Rosthern and at Saskatoon. The Rosthern site was lost due to a widespread frost on August 2.

Table 2 shows average days to flowering for all check varieties used in these experiments at Saskatoon and Rosthern. Limelight is an extremely early great northern type with dwarf growth habit.

Table 2. Days to flower for check genotypes in early flowering and maturity studies in 2001 - 2002

	2001 Trial 1	2001 Trial 2	2001 Trial 3	2001 Mean	2002 Trial 1	2002 Trial 2	2002 Trial 3	2002 Mean	2 year Mean	+/- Pintium
CDC Pintium	47.0	45.0	46.0	46.0	52.5	52.5	51.5	52.2	49.1	0.0
CDC Crocus	45.5	42.0	43.5	43.7	55.5	54.0	53.5	54.3	49.0	-0.1
Canario 107	48.0	44.5	45.5	46.0	52.5	53.5	54.0	53.3	49.7	0.6
Limelight (G2883)	42.0	40.0	41.0	41.0	54.0	53.0	52.5	53.2	47.1	-2.0
Rabia de Gato	56.0	56.0	56.0	56.0	56.5	56.5	57.0	56.7	56.3	7.2
Othello	52.0	52.0	51.0	51.7	58.0	56.0	57.0	57.0	54.3	5.2
Viva	51.0	53.0	47.0	50.3	55.5	57.0	57.0	56.5	53.4	4.3
Bola 60 Dias	44.5	44.0	43.5	44.0	53.5	53.0	54.0	53.5	48.8	-0.4
CDC Expresso	45.5	43.0	47.5	45.3	56.5	54.0	54.0	54.8	50.1	1.0
Earliray	46.0	46.5	46.5	46.3	55.5	53.5	54.0	54.3	50.3	1.2
Mean	47.8	46.6	46.8	47.0	55.0	54.3	54.5	54.6	50.8	1.7

Results from 2001 and 2002 suggest that it may be possible to reduce maturity requirements by a few days relative to CDC Pintium. Checks used in this study were the earliest known parents available from CIAT collections of both Andean and

Mesoamerican germplasm . Trials in 2001 and 2002 were grown at two locations. Each trial consisted of the 10 checks plus 71 selected lines. From the germplasm selected from the early part of the project we again evaluated genotypes for use as parents based on the combination of early maturity, plant height and seed type. Tables 3,4 and 5 present summaries of the flowering and maturity data for all check lines plus all lines with days to flower less than the earliest checks. Most lines were selected from the SC 11801 population. It is clear that early flowering did not necessarily lead to early maturity, and that it is possible to develop lines with both earlier flowering and earlier maturity than the check cultivars, including CDC Pintium. Based on seed type, selected lines that show the combination of early flowering and early maturity are now in use as parents in the breeding program.

A mutation breeding program was initiated in the spring of 2001 as a potential means to develop early maturity in exotic market classes from South America, such as tortola from Chile. The M_0 generation was grown in a polyhouse in the summer of 2001. A few M_1 and M_2 plants were grown in rows in the summer of 2002. To date no conclusions can be drawn from this work.

Very large-seeded round red beans from Colombia were grown in the growth room in the summer of 2001 and crossed with locally adapted red bean breeding lines. The original lines are extremely sensitive to photoperiod and classified as Type IV climbers. The will do not produce seed under field conditions at Canadian latitudes. An additional round of crosses were made to produce three-way hybrids as a way to transfer the colour and size to a better adapted background. The first bi-parental and tri-parental hybrid F_2 populations were grown in the field in 2002. Results showed that crosses were completely fertile, that most F_2 plants were daylength sensitive, and that a minimum three-way cross with two adapted parents is necessary to have any chance of recovering adapted germplasm or seed type. A congruity backcrossing scheme was implemented in 2002 to develop daylength insensitive genotypes with the required seed characteristics.

A similar strategy was employed to initiate development of adapted yellow bean germplasm for Saskatchewan. All original yellow-seeded parents are too late-maturing for successful cultivation. A few single and three-way cross combinations were evaluated for the potential to produce adapted germplasm with acceptable seed type. Preliminary observations show that adaptation and seed type are under the control of fewer genes compared to the situation with the Colombian round red types. Selections were made within Mexican landraces to develop a few parental sources with early maturity based on field evaluations in 2002.

Table 3. Days to flower and maturity for checks varieties and selected lines from dry bean crosses DC11800 and DC 11801for 2001 - 2002 in bean early maturity study Test No. 1

Population	Line	2001 Days to flower	2001 Days to flower +/- Pi	2002 Days to flower	2001-02 Mean Days to flower	2001-02 Mean Days to flower +/- Pin	2001 Days to mature	2001 Days to mature +/- Pintium	2001 Days from flower to maturity	Growth habit	Plant height
check	CDC Pintium	47.0	0.0	52.5	49.8	0.0	91	0.0	44.0	I	
check	CDC Crocus	45.5	-1.5	55.5	50.5	0.7	95	4.0	49.5	III	
check	Canario 107	48.0	1.0	52.5	50.3	0.5	102	11.0	54.0	I	
check	Limelight (G2883)	42.0	-5.0	54.0	48.0	-1.8	89	-2.0	47.0	III	
check	Rabia de Gato	56.0	9.0	56.5	56.3	6.5	99	8.0	43.0	II	
check	Othello	52.0	5.0	58.0	55.0	5.2	100	8.5	47.5	III	
check	Viva	51.0	4.0	55.5	53.3	3.5	96	5.0	45.0	III	
check	Bola 60 Dias	44.5	-2.5	53.5	49.0	-0.8	97	6.0	52.5	I	
check	CDC Expresso	45.5	-1.5	56.5	51.0	1.2	103	12.0	57.5	I	
check	Earliray	46.0	-1.0	55.5	50.8	1.0	90	-1.0	44.0	I	
DC11800	10c	41.5	-5.5	52.5	47.0	-2.8	93	2.0	51.5	I	very short
DC11801	11a	43.5	-3.5	52.0	47.8	-2.1	94	3.0	50.5	I	medium
DC11801	11b	43.0	-4.0	52.5	47.8	-2.1	91	-0 5	47.5	I	medium
DC11801	28b	40.5	-6.5	52.0	46.3	-3.6	89	-2.0	48.5	I	very short
DC11801	30a	43.0	-4.0	53.5	48.3	-1.6	95	4.0	52.0	I	medium
DC11801	38a	42.5	-4.5	53.0	47.8	-2.1	91	0.0	48.5	I	tall
DC11801	48c	41.5	-5.5	53.5	47.5	-2.3	93	1.5	51.0	I	very short
DC11801	52b	43.0	-4.0	51.5	47.3	-2.6	89	-2.0	46.0	I	tall
DC11801	61a	40.5	-6.5	52.5	46.5	-3.3	88	-3.5	47.0	I	very short
DC11801	73a	41.5	-5.5	54.0	47.8	-2.1	88	-3.0	46.5	I	medium
DC11801	110c	44.5	-2.5	50.5	47.5	-2.3	97	5.5	52.0	I	medium
DC11801	111d	45.0	-2.0	50.5	47.8	-2.1	99	7.5	53.5	I	medium

Table 4. Days to flower and maturity for checks varieties and selected lines from dry bean cross SC11801for 2001 - 2002 in bean early maturtiy study Test No.2

Population	Line	2001 Days to flower	2001 +/- Pintium	2002 Days to flower	2001-02 Mean Days to flower	2001-02 Mean +/- Pintium	2001 Days to mature	2001 Days to mature +/- Pintium	2001 Days from flower to maturity	Growth habit	Plant height
check	CDC Pintium	45.0	0.0	52.5	49.5	0.0	87.0	0.0	42.0	I	
check	CDC Crocus	42.0	-3.0	54.0	47.8	-1.8	94.5	7.5	52.5	III	
check	Canario 107	44.5	-0.5	53.5	48.8	-0.8	98.0	11.0	53.5	I	
check	Limelight (G2883)	40.0	-5.0	53.0	48.3	-1.3	88.0	1.0	48.0	III	
check	Rabia de Gato	56.0	11.0	56.5	56.0	6.5	96.5	9.5	40.5	II	
check	Othello	52.0	7.0	56.0	54.5	5.0	97.0	10.0	45.0	III	
check	Viva	53.0	8.0	57.0	53.0	3.5	96.5	9.5	43.5	III	
check	Bola 60 Dias	44.0	-1.0	53.0	49.0	-0.5	101.5	14.5	57.5	I	
check	CDC Expresso	43.0	-2.0	54.0	48.3	-1.3	99.5	12.5	56.5	I	
check	Earliray	46.5	1.5	53.5	49.3	-0.3	90.5	3.5	44.0	I	
SC11801	175a	42.0	-3.0	52.0	47.3	-2.3	90.0	3.0	48.0	I	very short
SC11801	144a	42.0	-3.0	53.0	47.3	-2.3	98.5	11.5	56.5	I	medium
SC11801	144d	42.0	-3.0	53.0	47.3	-2.3	95.5	8.5	53.5	I	medium
SC11801	141a	42.5	-2.5	54.0	47.5	-2.0	94.0	7.0	51.5	I	medium
SC11801	175d	42.0	-3.0	52.5	47.3	-2.3	91.5	4.5	49.5	I	medium
SC11801	158d	42.0	-3.0	51.5	47.5	-2.0	90.0	3.0	48.0	I	medium

Table 5. Days to flower and maturity for checks varieties and selected lines from dry bean cross SC11801for 2001 - 2002 in bean early maturtiy study Test No.3

Population	Line	2001 Days to flower	2001 +/- Pintium	2002 Days to flower	2001-02 Mean Days to flower	2001-02 Mean +/- Pintium	2001 Days to mature	2001 Days to mature +/- Pintium	2001 Days from flower to maturity	Growth habit	Plant height
check	CDC Pintium	46.0	0.0	51.5	48.8	0.0	87.0	0.0	41.0	I	
check	CDC Crocus	43.5	-2.5	53.5	48.5	-0.3	92.5	5.5	49.0	III	
check	Canario 107	45.5	-0.5	54.0	49.8	1.0	93.5	6.5	48.0	I	
check	Limelight (G2883)	41.0	-5.0	52.5	46.8	-2.1	87.0	0.0	46.0	III	
check	Rabia de Gato	56.0	10.0	57.0	56.5	7.7	98.5	11.5	42.5	II	
check	Othello	51.0	5.0	57.0	54.0	5.2	94.0	7.0	43.0	III	
check	Viva	47.0	1.0	57.0	52.0	3.2	97.5	10.5	50.5	III	
check	Bola 60 Dias	43.5	-2.5	54.0	48.8	0.0	103.0	16.0	59.5	I	medium
check	CDC Expresso	47.5	1.5	54.0	50.8	2.0	97.0	10.0	49.5	I	medium
check	Earliray	46.5	0.5	54.0	50.3	1.5	92.0	5.0	45.5	I	medium
SC11801	195a	42.0	-4.0	50.5	46.3	-2.6	98.0	11.0	56.0	I	medium
SC11801	209d	41.0	-5.0	52.0	46.5	-2.3	96.0	9.0	55.0	I	medium
SC11801	210c	42.0	-4.0	50.5	46.3	-2.6	96.5	9.5	54.5	I	very short
SC11801	210d	41.0	-5.0	51.0	46.0	-2.8	86.5	-0.5	45.5	I	very short

2.1.4 Development of germplasm with better harvestability through introgression of the reduced lignin trait

Results from 2000 suggested that under cool wet conditions the reduced lignin trait may be neutral or possibly negative by reducing the rate of drydown. Pre-breeder microplots of some advanced black bean lines had homozygous expression of this trait in 2001. These pre-breeder sub-lines were harvested separately and were used in direct comparisons to normal pod type sub-lines in 2002. Under drought conditions, harvestability may be enhanced with this trait. Some breeding lines exhibiting this trait were selected each year in each generation of the breeding program to help develop adapted germplasm for use as parents.

2.1.5 Other Developments in Bean Germplasm Development

Dr. Tom Warkentin successfully applied for a grant for laboratory infrastructure from the Canadian Foundation for Innovation. An upgrade of the pulse molecular biology laboratory is in progress, allowing for cost reduction and improved efficiency for screening using molecular markers. This has the most immediate impact for the dry bean crop for which numerous markers are available for screening of disease resistance genes.

Dr. Kirstin Bett of the Department of Plant Sciences provided much useful laboratory expertise in the last year of this project. She helped design marker-assisted breeding strategies for several traits and is currently developing new project proposals in collaboration with other bean breeders across Canada. Dr. Bett has also submitted a Collaborative Research and Development project to Saskatchewan Pulse Growers and NSERC in the general area of improving cold and frost tolerance in the bean crop. She has also applied for CFI infrastructure funds to further develop the marker assisted selection laboratories available for pulse research.

Pulse Canada sponsored the first-ever Canadian bean breeders mission to Mexico to help gain insight into the future demand for beans by Mexican consumers. This is particularly important in light of the phasing out of duties on bean imports from Canada in 2008 under the NAFTA agreement. It was generally agreed that rapid development of adapted germplasm with early maturity, suitability for Canadian agronomic systems, and suitable seed types should be a high priority. The market classes most suitable for this effort are flor de junio, mayacoba (yellow) and flor de mayo (in progress at the CDC).

2.2 Chickpea

2.2.1 Screening and monitoring of current sources and development of new sources of ascochyta resistance

In most years during this project, natural ascochyta infection was severe beginning in early July. Infection was continuous and repeatable across replications and locations, even in years with dry conditions. The screening system is very effective.

Nurseries from ICARDA and ICRISAT ranging from F_2 to F_6 were sown in the spring of each year of this project. A system for screening of CDC lines at ICARDA was developed in collaboration with Dr. R. Malhotra, principal chickpea breeder at ICARDA. Dr. Malhotra and Dr. Jagdish Kumar (principal chickpea breeder at ICRISAT) visited Saskatoon in November, 2001 and assisted with the final design of the collaborative germplasm evaluation system. Progress was also made in developing a germplasm exchange with Dr. Ted Knights and Mr. Michael Materne, chickpea breeders from Australia. We have also regularly exchanged germplasm with the US breeding program at Washington State University. We are now fully and systematically linked to the appropriate ascochyta resistance breeding programs around the world.

We have focussed on using early maturing selections from introduced lines as parents in crosses with locally developed lines. We also have confidence that many CDC lines in the desi chickpea breeding program have improved levels of resistance, at least to the best level that currently exists in the world.. In 2001 and 2002 we confirmed that many kabuli breeding lines show the same level of resistance.

Field observations from 2000-2002 confirmed that in the Saskatchewan environment, the simple leaf trait interacts with ascochyta resistance genes – simple leaf types appear to be more susceptible under heavy disease pressure and will require more careful management in commercial production systems.

2.2.2 Development of germplasm that emphasizes ascochyta resistance combined with early maturity

In 2001 and 2002 we were able to evaluate numerous breeding lines derived from three-way crosses with ICCV 96029, one of the earliest maturing breeding line in the world according to research conducted at ICRISAT in the 1990s. Under the difficult field drought conditions experienced in 2001 and 2002 at all chickpea nursery locations, many lines derived the early maturing background were much higher yielding compared to check varieties (see Table 6). Much of the yield gain may be attributable to the enhanced early maturity. We hypothesize that the earlier maturity allows more seed filling prior to extreme terminal drought. The early maturity of these lines may have major implications for reduction of risk in chickpea production in Saskatchewan. For example, evidence from farmer experience and research experience indicates that later seeding may help chickpea crops avoid infection from airborne ascospores in the spring and reduce early season cold soil stress.

Table 6. Performance data for entries in the 2002 Desi Chickpea EliteTrial in Saskatchewan

Entry	2002 data							2001 data		
	Yield %	Ht cm	DTF days	AB 1-9	Mat 1-5	Size	Shape	SW mg	Color 2001	Mat
Myles	*100*	46	53	6.0	2.3	MS	A	210	T	E
CDC Desiray	*91*	46	52	5.5	2.3	MS	P	220	LT	E
CDC Anna	111	47	52	5.5	*2.6*	MS	P	220	T	M
CDC Nika	*98*	49	49	6.0	2.5	L	P	320	T	M
92073-40	124	50	48	6.0	*2.6*	ML	P	280	T	E
304-51	132	49	*54*	5.0	*2.7*	M	P	220	T	M
296-3-38	132	54	*54*	5.0	*2.7*	MS	P	260	T	M
304-78	131	47	53	5.0	*2.8*	MS	P	210	T	M
304-40	143	46	53	5.0	2.5	M	P	250	T	E
304-82	131	44	53	5.0	2.3	M	P	220	T	M
296-3-39	102	50	53	5.0	*2.8*	MS	P	250	T	M
304-31	164	38	52	5.0	2.0	M	P	240	T	E
221-24	*97*	43	*54*	*7.0*	2.5	M	A	230	G	E
304-22	168	42	51	5.0	2.2	M	P	260	T	E
304-7	134	43	52	5.0	2.4	M	P	260	T	M
304-46	145	44	53	5.0	2.4	M	P	240	T	M
Mean	125	46	52	5.4	2.5					
Sites	4	2	2	1	5					

Cross 304 = 92073-60D/(92056-8/ICCV 96029)

2.2.3 Development of chickpea germplasm with determinate growth habit

As reported previously, determinate chickpea lines obtained from ICRISAT were not determinate when grown in the Saskatchewan environment. The resources originally directed toward this effort were mainly shifted to speeding up development of the early maturity and ascochyta resistance breeding objectives. In collaboration with Dr. Rosalind Ball, we have developed hypotheses regarding possible physiological induction of determinate growth. With the assistance of an independently funded ADF project, these hypotheses will be rigorously tested. A graduate student from Ethiopia, Mr. Yadeta Anbessa, is conducting this research. He is an experienced chickpea breeder with international experience at ICARDA.

2.2.4 Development of kabuli chickpea germplasm combining ascochyta resistance and large seed size

In each crossing cycle we attempt to introduce parents with larger seed size. The association with late maturity in the base germplasm poses some problems with field screening, but the conditions of 2001 were favourable because all chickpea plants matured, allowing much larger sample sizes from segregating populations. Conditions in

2002 were less favourable, but we expect to have made progress for early maturity combined with ascochyta blight. We systematically incorporated new sources in each new crossing block, often using parental lines with similar seed size and maturity compared to CDC Xena and CDC Diva. The process of developing very large seeded kabuli types is a slow procedure, but consistent progress is being made through a modified recurrent selection system.

Most kabuli germplasm is inherently later maturing except for small-seeded types from the Indian sub-continent. Some of the best sources of ascochtya resistance are round-seeded kabuli types from Bulgaria (for example, the variety Amit). We have combined these traits into germplasm that combines 8-10 mm size kabuli type with earlier maturity and improved ascochyta resistance (Table 7).

Table 7. Performance of entries in the 2002 Kabuli Chickpea Elite Trial in Saskatchewan

	2002 data								2001 data	
Entry	**Yield**	**Leaf**	**Ht**	**DTF**	**AB**	**AB**	**Mat**	**Size**	**Size**	**Shape**
	% Amit		**cm**	**days**	**1-9**	**%**	**1-3**			
Sanford	*75*	U	56	*54*	*7.5*	*38*	*2.5*	L	ML	N
CDC Xena	*72*	U	45	52	*7.5*	*38*	2.3	VL	L	N
Amit	100	F	49	*53*	3.5	5	*2.5*	S	MS	R
95NN-29	167	F	44	52	3.5	5	*2.8*	ML	ML	N
95NN-12	149	F	40	51	3.8	7	1.9	M	ML	N
95NN-19	154	F	48	52	3.8	5	*2.8*	ML	ML	N
95NN-28	167	F	44	52	3.5	5	*2.6*	ML	ML	N
95NN-32	159	F	47	52	3.5	5	*2.5*	ML	M	N
95NN-33	161	F	49	*53*	3.8	6	*2.8*	ML	ML	N
97-Indian2-96	116	F	42	52	4.5	9	2.4	L	L	N
97-Indian2-112	145	F	41	51	4.8	9	2.4	L	L	N
97-Indian2-125	124	F	46	52	4.5	7	2.1	L	L	N
239-10	159	F	40	50	5.0	9	1.9	S	MS	N
172-7	158	F	45	51	4.8	7	2.0	M	MS	N
264-5	176	F	43	50	4.5	7	2.3	M	MS	N
264-2	160	F	46	50	4.5	7	2.0	M	MS	N
242-4	145	U	43	52	6.3	*38*	1.9	ML	ML	N
239-16	165	F	45	51	5.0	9	2.3	M	M	N
242-1	161	U	44	52	6.0	*38*	1.9	L	ML	N
265-1	140	F	46	50	5.3	9	2.1	ML	ML	N
Mean	143		45		4.8	13	2.3			
Sites	4		2	2	2	1	4			

F-fern leaf type; U – unifoliate type L-large M-medium S-small N-normal

2.3 Field Pea

2.3.1 Development of an improved germplasm base for Mycosphaerella tolerance

Results under irrigation at Outlook in 2001 and 2002 confirmed that screening for Mycosphaerella tolerance will be most effective if medium infection pressure can be developed and maintained. This requires the use of irrigation in dry years like 2001 and 2002. The regular F4 screening nursery and all other related research under dryland conditions at Saskatoon in 2001-2 were ineffective because of the hot dry weather. If progress is to be made, we will need reliable access to an irrigation system suitable for growing pea plots

Results from the 2001 Field Pea Co-operative Test A and B and analysis of replicated disease screening trials at Morden, MB and Outlook, 2002, showed that improvements in in Mycosphaerella are occurring slowly and steadily occurring (Table 8). Lines like CDC0106 consistently show the lowest disease scores, and lines like CDC0104 and CDC0108 combine low average scores with low scores for lodging. This confirms the results of other research projects that resistance to Mycosphaerella blight is partly associated with lodging resistance in pea.

Table 8. Performance data and Mycosphaerella blight scores for checks and second year **CDC entries in the 2001-2002 Pea Coop Trial in Western Canada***

		2002	2001-2	2002	2002	2002	2002	2001	2001-2
							Mycosphaerella		
	Seed	DTF	Yield	Lodging	Mat	Ht	score		
Entry	type	days	%	1-9	days	cm		1-9	
Carrera	Y	57	97	6.3	106	53	6.0	8.3	7.2
Eclipse	Y	59	105	3.5	110	61	6.0	7.0	6.5
CDC Mozart	Y	58	100	6.2	106	58	6.0	7.8	6.9
Nitouche	G	59	102	3.7	107	65	5.5	7.3	6.4
CDC0103	Y	60	120	6.0	106	66	6.5	6.3	6.4
CDC0104	Y	57	120	3.7	102	63	4.0	7.8	5.9
CDC0105	Y	58	114	7.0	102	58	6.0	7.0	6.5
CDC0106	G	57	113	6.8	103	57	5.0	6.7	5.9
CDC0107	G	58	115	6.8	105	60	6.0	7.2	6.6
CDC0108	Y	58	122	5.3	103	69	4.5	7.2	5.9
Mean		59		5.1	106	61			
Sites		1	13	2	2	2	1	1	2

* Only 2 sites for 2002 yield performance available by Dec 31, 2002.
Yield is % of CDC Mozart

Dr. Bob Conner of AAFC Morden has also initiated a project that involves evaluation of potential new sources of Mycosphaerella resistance. We have also initiated nursery exchanges with pea breeding programs in Europe (Cebeco Seeds), in the USA (USDA in Pullman) and Australia (Victorian Insitute of Dryland Agriculture).

2.3.2 Rapid development of an improved germplasm base for powdery mildew

When powdery mildew occurs early, for example in late June 2001 in eastern Saskatchewan and larege regions within the western prairies in both 2001 and 2002, significant yield losses can occur. Commercial experience generally confirms research that shows that powdery mildew resistance will increase yield on average by reducing crop loss in heavy mildew years (mild droughts). Other significant consequences of heavy powdery mildew resistance is prevention of the buildup of flammable spores and dust on combines, and reduction of interaction with pre-harvest desiccants.

During the course of this project, a system of gamete selection was implemented to allow for rapid and efficient screening of powdery mildew resistance in F_1 and F_2 populations for all market classes. Most pre-coop CDC breeding lines are now resistant, and many of the current CDC Field Pea Co-operative Trial entries combine powdery mildew resistance and high productivity. The breeding system has been streamlined to accommodate selection for powdery mildew resistance at very little economic or genetic cost. Results from Coop Trials in 2001 and 2002 clearly show that in most cases, powdery mildew resistant lines show yield advantages. Most pea breeders have accelerated the development and introduction of resistant varieties for the prairies. Table 9 shows very clearly that lines with powdery mildew resistance tend to have significant yield advantages over susceptible check varieties. Some susceptible breeding lines maintain high yield, but there is obviously no yield penalty when powdery mildew resistance is incorporated into adapted pea breeding lines.

Table 9. Performance data and powdery mildew reaction for checks and CDC entries in the 2002 Pea Coop Trial in Western Canada*

Entry	2002 Coop Trial	Year in Trial	Seed type	2002 Yield % CDC Mozart	Powdery mildew reaction
Carrera	A	check	Y	79	S
Eclipse	A	check	Y	100	R
CDC Mozart	A	check	Y	100	R
Nitouche	A	check	G	89	S
CDC0103	A	2	Y	130	R
CDC0104	A	2	Y	105	S
CDC0105	A	2	Y	112	R
CDC0106	A	2	G	104	S
CDC0107	A	2	G	118	S
CDC0108	A	2	Y	125	S
CDC653-8	A	1	Y	123	R
CDC672-1	A	1	G	111	R
CDC647-1	A	1	G	121	R
Carrera	B	check	Y	67	S
Eclipse	B	check	Y	81	R
CDC Mozart	B	check	Y	100	R
Nitouche	B	check	G	84	S
CDC0101	B	2	Y	103	R
CDC0102	B	2	Y	112	R
CDC651-2	B	1	Y	116	R
CDC728s-7	B	1	Y	113	R
CDC715s-4	B	1	Y	123	R

* 2 sites available by December 31, 2002

2.3.3 Development of better bleach tolerance in green field pea

An effective low cost system for bleach tolerance screening was developed during this project. The traditional method for screening involves allowing green pea seeds to soak up water, then exposing the seeds to light followed by planting of the unbleached seeds. The new method involves simulation of supermarket storage conditions. Dry seeds are stored in small poly bags,

All generations in the green pea breeding program are now routinely screened for improved bleach tolerance. The results of introducing the low cost, consistent procedure

for screening for bleach tolerance are now showing up in registration trials. All CDC lines in the 2001 Field Pea Co-operative Trial had bleaching scores equal to or better than the current check variety Nitouche in a year with high potential for bleaching. The improved lines also have improved yield potential. The yield gap between yellow and green breeding lines is no longer noticeable. Within a few years, we foresee that Canadian green peas will no longer be discounted on the basis of quality in the export market.

Table 10. Peformance data for green cotyledon entries in the 2001 Pea Coop Trial in western Canada

	Seed colour	Yield (kg/ha)	Days to mature	Plant height cm	Lodging (1-9)	Seed weight (mg)	Seed shape	Bleach score (1-5)	Seed coat breakage (%)
Carrera	Y	3642	95	52	4.0	228	2.7		9.2
Eclipse	Y	3837	99	64	3.5	231	2.7		5.5
CDC Mozart	Y	3627	97	55	4.6	198	2.5		4.4
Nitouche	G	3774	98	69	3.5	238	2.5	3.0	4.1
E-1	G	3608	98	58	4.7	260	3.2	3.2	8.7
E-2	G	3862	98	57	4.1	257	2.7	3.3	5.4
E-3	G	4164	98	53	3.5	250	2.6	3.4	11.2
E-4	G	4094	100	64	3.1	255	2.5	3.1	8.5
CDC0001	G	3569	98	67	3.1	226	2.5	3.0	0.9
CDC0011	G	3704	97	66	3.1	228	2.2	3.0	2.0
CDC0106	G	4156	96	66	4.1	177	2.5	3.0	3.1
CDC0107	G	4169	98	63	4.6	176	2.3	2.8	1.5
CDC0110	G	4158	97	68	4.9	171	2.8	3.1	9.6
Mean		3947	97	63	3.7	220	2.6	3.1	6.3
CV		12.3	1.6	7.9	23.1	9.2	10.5	8.6	71.9
LSD (0.05)		408	1.3	4.2	0.7	16.9	0.2	0.2	6.3
Sites		11	11	11	11	11	11	11	4

Note: Lines designated with E are from European breeding programs

2.4 Lentil

2.4.1 Development of high-yielding red lentil germplasm with acceptable shape and colour

Numerous cycles of screening for plump shape for were completed. Each year, all red lentils were rated on a family basis for plump shape before inclusion in F_3 disease nurseries. All advanced yield trials were evaluated for yield and seed shape – each year several lines were used as recurrent selections in the crossing program. We have started to develop a stream of yellow cotyledon germplasm with extra plumpness for potential market development of split yellow lentil in south Asia.

ICARDA lentil nurseries (more than 1000 plots) were seeded at the Goodale farm in each year of the project. New lines from Australia, New Zealand and USA were also included in various trials. Breeding lines in these nurseries were usually unadapted, however, the best adapted lines with the plumpest seeds were selected for use as parents. About 1000 lines originating from the Russian collection were grown at the AAFC farm in Saskatoon collaboration with Dr. Axel Diederichsen. In general, Russian-derived lentil lines are much better adapted than lines from the Middle East or South Asia. Approximately 30 lines were selected as potential parents in the breeding program based on canopy structure, adaptation and seed plumpness. During Pulse Canada trade missions to India and Turkey, commercial samples of red lentil were also collected. The best adapted lines with the plumpest seeds were used as parents in the breeding program.

The climatic conditions of 2001 and 2002 showed that many current red lentil varieties do not perform as well as in the relatively cool, wet seasons of 1999 and 2000. New red lentil breeding lines in Cooperative Trials and the advanced testing stage combine plump shape, disease resistance and high yield under drought conditions (Table 10).

Table 10. Performance of 2nd year red lentil lines in Lentil Coop Trial in western Canada 2001-2002

		Yield % of Milestone			Seed
	Cotyledon colour	Coop 2002	Coop 2001	Coop 2001-02	weight (g)
Milestone	Y	100	100	100	46
Crimson	R	65	80	72	45
CDC Blaze	R	81	75	78	44
CDC Robin	R	89	79	85	36
1254S-1	R	117	86	103	52
1145-3-6	R	119	98	109	47
1125-1-5	R	118	101	110	38
1110-13RY-5	R	111	97	105	42
No of sites		7	6	13	6

Figure 4 shows the seed coat and size characteristics of the potential new red lentil lines in comparison to current commercial types. Based on commercial feedback from various importers, lines with the same size, plumpness and seed coats as 1254S-1 will help Canada compete with Australia in the international red lentil market. Our next round of germplasm will combine the productivity and disease resistance of adapted red lentil lines with the very round shape of the Turkish types. We are now experimenting with the use of mass selection for roundness in early generations that are segregating for round seed shape.

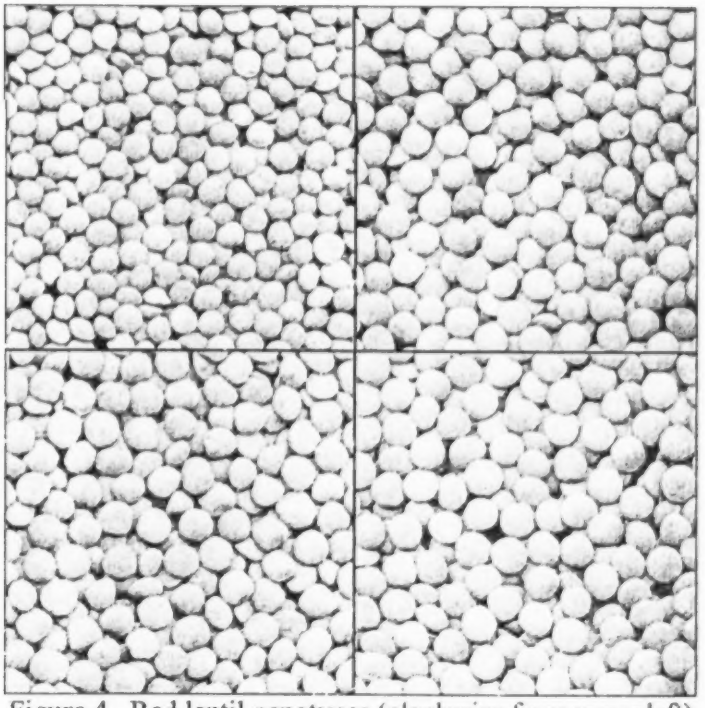

Figure 4. Red lentil genotypes (clockwise from upper left) CDC Robin, Crimson, 1254S-1 and CDC Blaze

2.4.2 Development of earlier maturing large seeded lentil germplasm

Based on performance of large-seeded lentil lines in various trials in 1999-2002, early maturity can add to yield potential. CDC Sedley and CDC Plato were distributed to seed growers in 2001 and 2002, respectively. Sedley is earlier flowering compared to all other large-seeded lentils released to date. It also has a more compact and erect canopy. Data collected on seed size distribution of all large-seeded entries in the Saskatchewan lentil regional trial clearly showed that CDC Sedley had the largest seeds. Plato is medium late but earlier than all other large green lentil varieties except Sedley. It is possible that early maturity enhances seed size of lentil in drought years. It may be possible to change the agronomy of lentil to produce improved size and colour.

We are routinely developing germplasm in which seed size and early maturity are independent traits. We have selected early maturing, disease resistant germplasm from various nurseries for inclusion in crossing cycles since the summer of 2000. Results from 2001 show that it is possible to produce lentil seeds that are significantly larger than Laird while maintaining higher yield. We will be able to develop varieties with a much higher proportion of 7 mm and 8 mm lentils.

Parental lines from ICARDA nurseries, Chile and the USA have been systematically used as the base germplasm for introducing the combination of early maturity and large seed size. In 2001, we began now making recurrent selections of advanced breeding lines

based on seed size. These were used in crosses with higher yielding advanced breeding lines to develop populations that combine yield, seed size and early maturity.

2.4.3 Other developments in lentil breeding

An international nursery exchange system was developed in collaboration with Mr. Michael Materne of VIDA, Australia and Dr. Fred Muehlbauer, USDA-ARS in Pullman, Washington. Starting in 2003 a schedule for hosted site visits will be organized on a rotating basis.

New research projects on lentil were initiated in the past year. The Australian program is now collaborating with us on development of Botrytis resistance in lentil, and we have plans to develop collaborations with the US program for development of resistance to Sclerotinia and Stemphylium.

We also plan to integrate our quality development in red lentil breeding in collaboration with participating members of the International Pulse Quality Committee, and in collaboration with companies such as SaskCan Pulse in Saskatchewan.

2.5 Conclusions

Improved germplasm was developed for all four pulse crops for most of the traits under research and development, with the possible exception of the determinate growth habit for chickpea and reduced pod lignin trait for dry beans. It may be necessary to pursue the goal of determinate growth habit in chickpea by introducing traits that indirectly affect determinate growth such as extra early maturity or dwarf growth habit. The direct and indirect benefits of improving the productivity and quality of Saskatchewan pulses are already evident to Select seed growers who are now receiving new varieties with measurable improvements in yield, disease resistance and quality. In almost all cases, we have successfully developed a stream of germplasm incorporating the various traits into breeding lines adapted to Saskatchewan. These improvements will become the new platform for development of other improved traits for Sastkchewan pulses.

2.7 Equipment

No equipment was purchased.

2.8 Project Developed Materials

A large number of breeding lines and new varieties are under evaluation at various stages for all stated objectives for all four pulse crops.

2.10 Acknowledgements

Support for this project was described at the Pulse Crop Research Chair advisory board meetings each year. Acknowledgement of ADF support was included in all presentations. Other presentations that described and acknowledged support for the project were made at Pulse Days, at winter extension meetings, at summer field days and at Select grower meetings in January and July of each year of the project.